



Effect of Gypsum and compost Application in Reclaiming Sodic soils at Small Scale Irrigation Farm in Bora District of East Shewa Zone, Oromia, Ethiopia

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General Note

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ABSTRACT

This experiment was conducted in Bora district of East Shoa Zone of Oromia, Ethiopia from 2017 to 2019 with the aim to evaluate the effect of sole and integrated application of Gypsum ($\text{CaSO}_4 \cdot \text{H}_2\text{O}$) and compost as soil salinity amendment. Onion variety (Adama red), the most commonly produced crop by farmers, was used as the test crop. Three levels of compost (0, 2.5, 5ton/ha) and three levels of Gypsum (0, 2t/ha, and 4t/ha gypsum) were factorial combined and arranged in RCBD design with three replications having

an area of 3mx4m for each. It was identified that integrated application of 4t/ha gypsum and 2.5ton/ha compost produced economically optimum yield (396Q/ha). The interaction effect of Gypsum integrated with compost in reducing soil sodicity indicators such as ESP (exchangeable sodium percentage), Na^+ concentration, pH, and EC were highly significant ($p < 0.05$). Sole application of Gypsum was also significantly affect ($p < 0.05$) the level of ESP, Na^+ , Ca^{2+} and EC. ESP and EC were very high at the control treatment and showed a decreasing trend as the level of Gypsum requirement increases from 50% to 100%. The main effect of compost significantly affected ($p < 0.05$) the level of pH showing a decreasing trend as the level of compost was increased. Crop yield was increasing as the level of compost and gypsum application level were increasing indicating that both materials are very important for improvement of production and productivity of land affected by salinity problem. Therefore, considering its economical importance and positive effect in soil salinity amendment potential, 100%GR integrated with 2.5ton/ha compost was recommended as the best strategy in reclamation of salt affected soil.

Keywords: Soil salinity, Application, Gypsum, Compost, Reclamation, small scale Irrigation

1. INTRODUCTION

Soil degradation, which can be caused by salinity and sodicity, is considered as an environmental problem with severe adverse effects on agricultural productivity, particularly in arid and semiarid regions (Qadir et al., 2006). It is considered the most critical environmental stress which can negatively affect plant growth and the metabolism process (Rodriguez-Navarro & Rubio, 2006). Salinity usually appears in the arid and semi-arid areas where the evaporation process is higher than the total precipitation (Qadir et al., 2006). It was reported that groundwater is a permanent source of soil salinization that causes poor productivity in the irrigated areas Moukhtar et al. (2003).

In Ethiopia, it was reported that, there are over 11 million hectares of unproductive naturally salt affected wastelands (Abdel-Fattah MK, 2012). It is the major problems in irrigated areas of arid and semi-arid region where there is a high evapotranspiration rate in relation to precipitation (Abas et al. 2016). This study also revealed that about 44 million ha (36% of the country's total land areas) are potentially susceptible to salinity problems.

Bora district is found in the rift valley of Ethiopia where soil sodicity problem is very high due to higher evapo-transpiration (Tamire, 2004). According to the study by Kasahun *et al.* (2016), about 75% of the farmers in Bora district has been using ground water for irrigation that were found sodic. pH > 8.5, EC < 4ds/m, and ESP >31 were recorded in these districts at the farmers who are using ground water for irrigation.

There are many strategies that can be used to improve salt affected cropland. One of the approaches for the economic utilization of moderately salt affected land is to grow salt tolerant plant species with appropriate agricultural practices (Mokoi & Verplancke, 2010). The chemical remediation is one of these reclamation strategies (Sharma & Minhas, 2005). The application of Calcium amendments can improve different properties of soil and act as soil modifiers that can prevent development of sodicity which is directly related to plant growth, crop productivity and crop yields (Wong et al., 2009; Chintala et al., 2010). Specific chemical amendments such as calcium chloride ($\text{CaCl}_2 \cdot 2\text{H}_2\text{O}$) and gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$) can be used as direct source for Ca^{2+} cation; however gypsum is normally available and relatively cheap. Gypsum plays a significant role in the reclamation of saline-sodic soils by providing a Ca^{2+} cation to replace the exchangeable Na^+ from the colloid's cation exchange positions and leaching it out from the root zone (Sharma & Minhas, 2005, Mohamedet *al.* 2011). Soil salinity management interventions usually vary from place to place depending on the type of soil salinity, the availability of the materials and awareness on soil salinity management practices. Gypsum has become an efficient to reclaim sodic soils (Fisher and Madeline, 2011). The study indicated that, application of gypsum increases concentration of Ca^{2+} in soil solution to substitute the adsorbed sodium, hence overcome the dispersion effects of Na^+ and improve the soil structure in the dispersed soils.

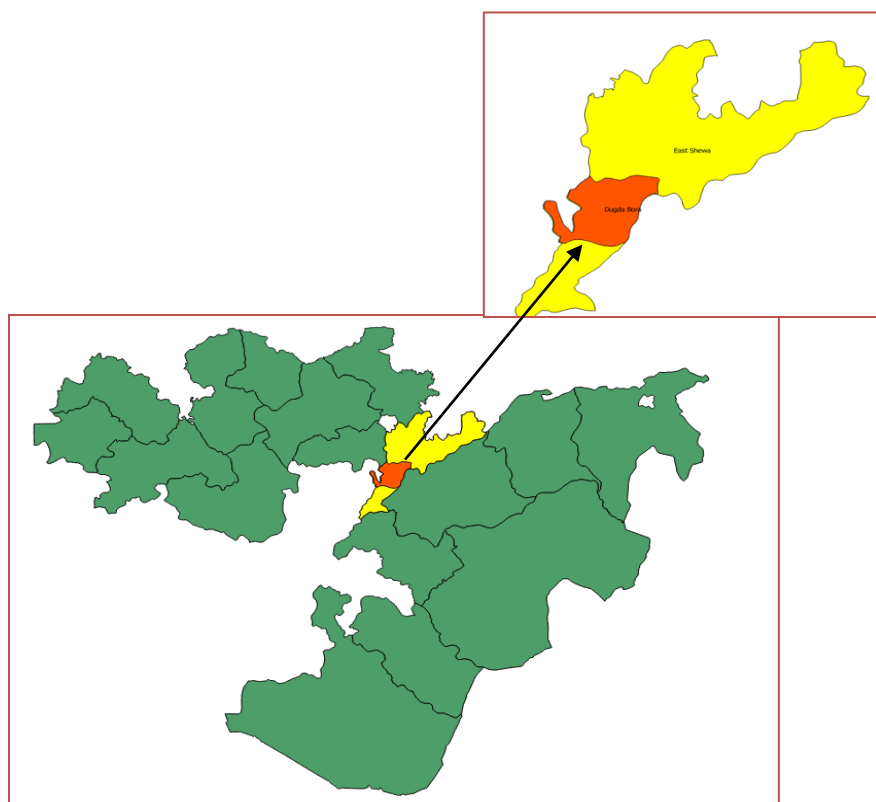
Organic material amendments like application of compost increases soil CO_2 concentrations and releases H^+ when it dissolves in water. The released H^+ enhances CaCO_3 dissolution and liberates more calcium for sodium exchange (Ghafoor et al. 2008). The addition of compost in to salt affected soil has been successful in improving soil properties of sodic soils (Islam MA, et al., 2017). However, the effect of integrated application of both compost and Gypsum for soil sodicity reclamation was not known.

2. OBJECTIVES

- 2.1 To evaluate the impact of Gypsum and compost application on reclamation of salt affected irrigated land
- 2.2 To recommend the best application rate of Gypsum and compost for sodicity management

3. MATERIAL AND METHODS

The study was conducted in Bora District of East Shewa Zone of Oromia which is located 100km far from capital city Addis Ababa to the south. Geographically located at 39.02 E, 8.37°N (Kasahun et al., 2016). In this district, irrigation is the main economic activity for many small scale farmers and large scale investors. The district is generally characterized by dry low land agro-climate with the altitude ranging from 1676-1750 m.a.s.l. The rainfall pattern is erratic, insufficient mean monthly precipitation and higher potential evapo-transpiration. Mean daily temperature is 20°C during the rainy season. Sandy loam is the dominant soil texture identified during the soil salinity assessment and characterization (Kasahun et al., 2016). As far as vegetation is concerned, mid rift valley in general and Bora district in particular is characterized by scattered acacia wood lands.



Geographical location of Bora district in East Shoa Zone of Oromia region

3.1. Farmers Selection and Treatments

Two farmers who are using ground water for irrigation were purposively selected depending on their interest for evaluation soil salinity management. In this trial, three levels of Gypsum requirement (0, 2 and 4t/ha) and three levels of compost (0, 2.5, and 5t/ha) were factorial combined. The level of Gypsum requirement was determined by the initial level of CEC, ESP initial, plan of ESP at final and 1.72t Gypsum which is the amount of Gypsum required to reduce a unit of sodium in the soil (Mohamed, 2012).

Therefore, Average CEC at initial was 17 meq/100gm, ESP initial = 25%, ESP final (required to be reached by reclamation) = 10%

$$GR \text{ (Gypsum requirement)} = (ESP_i - ESP_f) / 100 * CEC * 1.72 \text{ton} = (25 - 10) / 100 * 17 * 1.72 = 4.3 \text{ton/ha}$$

The level of compost was determined based on the amount of nitrogen fertilizer that the farmers are currently applying and the quality of conventional compost in terms of total nitrogen content. Accordingly, on average the farmers were using 100kg urea (46kg N/ha) for onion. The quality of compost was determined after laboratory analysis; accordingly, it contained 1% total nitrogen. Therefore, about 4.6t/ha which is nearly 5ton/ha compost can supply or substitute 46kg N (100kg urea). About 200kg/ha NPS was used based on the farmers practice that was applied uniformly for all plots at all trial sites.

3.2. Treatments

1. Control (without compost and gypsum)

2. 2.5 ton/ha Compost
3. 5t/ha Compost
4. 50%GR (2t/ha)
5. 100%GR (4t/ha)
6. 2.5t/ha Compost+50%GR (2t/ha)
7. 2.5t/ha Compost +100%GR (4t/ha)
8. 5t/ha Compost +50%GR (2t/ha)
9. 5t/ha Compost+100%GR (4t/ha) Onion variety, which is one of the major used by the farmers in the area, was used for evaluation. The treatments were replicated three times having 12m² (3m*4m) area for each plot and arranged using RCBD. Site management (weeding, pesticide application, monitoring and watering) were done uniformly for all plots and experimental sites.

3.3. Soil Sampling and Data Collection

Soil samples were collected from each plot before application and after harvesting to the depth of 20cm and were sent to soil laboratory for soil sodicity test. The extent of salinity before and after intervention were identified based on four main parameters such as EC (electrical conductivity), pH, ESP (exchangeable sodium percentage), SAR (sodium adsorption ratio) because these values are used in the guidelines for classification of salt affected soil by different authors (Gonzalez *et al.*, 2004, Qadir & Schubert, 2008). In addition, soluble cations such as CEC, Calcium, Magnesium, Sodium, and Potassium were analyzed. Crop yield was also taken and recorded to evaluate the effect of the treatments on total onion yield.

Table 1: Guidelines for classification of salt affected soil and water (Gonzalez *et al.*, 2004)

Soil classification	EC DS/m	SAR	ESP	PH
Sodic	<4	>13	>15	>8.5
Saline	>4	<13	<15	<8.5
Saline sodic	>4	>13	>15	<8.5

Sodium percentage calculated as:

$$ESP = \frac{[Na^+]}{CEC} * 100$$

Economic data

The partial budget analysis was performed the standard methodology designed by (CIMMYT, 1988). Input cost (cost of chemical fertilizer, Gypsum, seedling and compost), cost for land preparation, and labor cost were considered. The Marginal rate of return (MRR), which measures the amount of benefit gained for additional unit of cost or investment, was used as major criteria and calculated as the ratio of change in net income from each treatment and the control to the change in total variable cost for the treatment and the control.

$MRR = (NIT - NIC) / (TVCT - TVCC)$, Where MRR (Marginal rate of return), NIT (Net income from each treatment), NIC (Net income by the control), TVCT (Total variable cost for the treatment), TVCC (Total variable cost for the control)

Data Analysis: Finally, data were analyzed using SAS version 9.0 and MINITAB version 19 was used.

4. RESULTS AND DISCUSSION

Main and combined Effect of Gypsum and Compost on Crop yield

Main effect for Gypsum and compost application were highly significantly ($p < 0.05$) affected crop yield. Crop yield was also highly significantly ($p < 0.05$) affected by the combined application of Gypsum and Compost. Maximum crop yield (439Q/ha) was obtained from the combined application of 5t/ha compost and 4t/ha Gypsum followed by 5t/ha compost combined with 2t/ha gypsum that could gain about 406.7Q/ha. It was identified that high crop yield) was obtained from the combined application as compared with the sole application of compost and gypsum (table 2). About 275.55Q/ha and 325.00Q/ha onion yield was obtained from sole application of compost and gypsum respectively. In addition, it was identified that sole application of sole gypsum could gain high

crop yield as compared with sole application of compost indicating that gypsum application is highly important in management of salt affected soil (table 2). Low crop yield was obtained from the control treatment (237.18Q/ha) where neither compost nor Gypsum was applied. This is highly in agreement with previous study by (Hanay et al., 2004) in Tanzania. In this study, maize yield increased by 54.1% and 82.2% when compost and gypsum were applied alone respectively. However, combining the two amendments increased maize yield by 104.2%. On the other hand, main effect for the year, interaction effect of year and treatments were not significant indicating that onion yield was not significantly affected by year variation (figure 1).

No.	Treatments
1.	Control
2.	2.5 ton/ha Compost
3.	5t/ha Compost
4.	50%GR (2t/ha)
5.	100%GR (4t/ha)
6.	2.5t/ha Compost+50%GR (2t/ha)
7.	2.5t/ha Compost +100%GR (4t/ha)
8.	5t/ha Compost +50%GR (2t/ha)
9.	5t/ha Compost+100%GR (4t/ha)

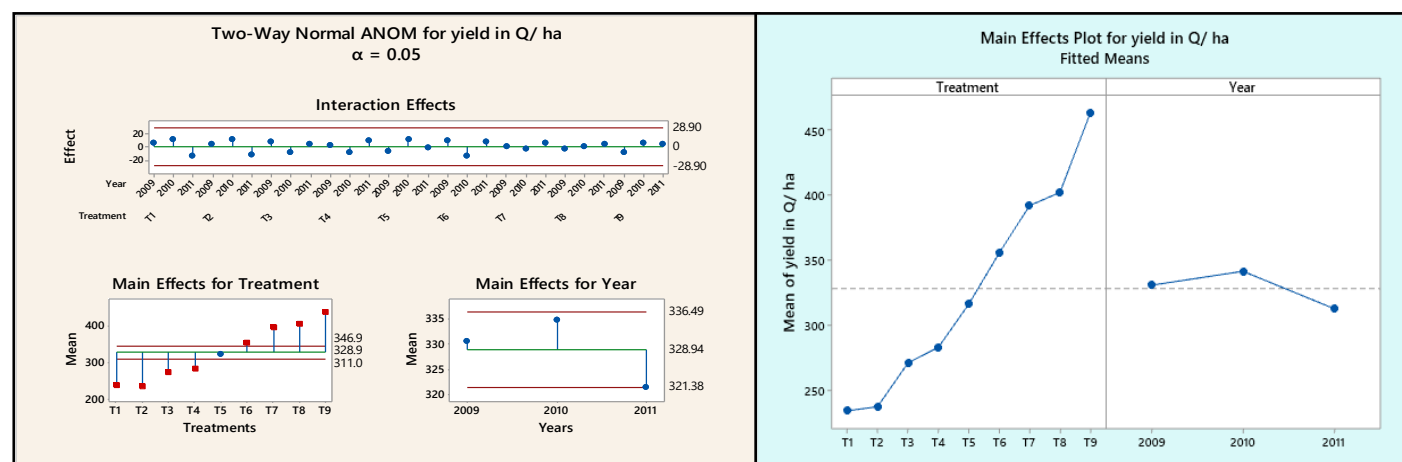


Figure 1: Main and interaction effect of treatments and years

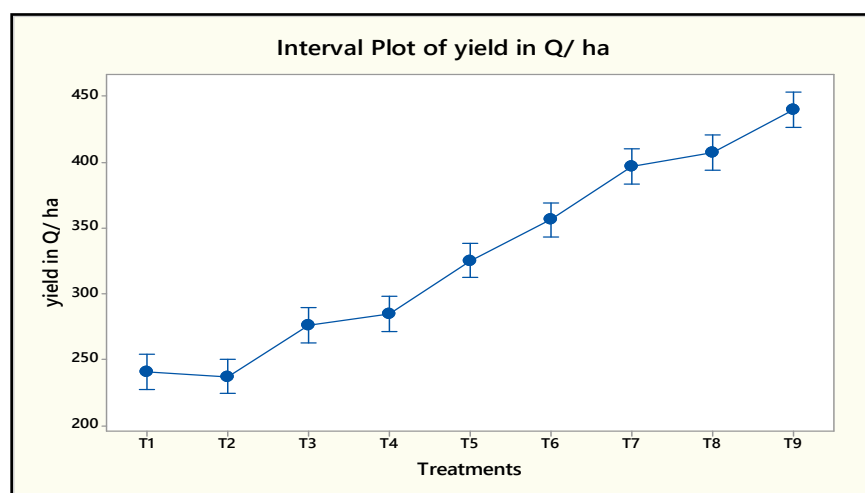


Figure 2: Change in yield between the treatments

The crop yield showed an increasing trend with increased level of compost and gypsum (figure 2). The relative yield advantage against check was calculated for each treatment (table 2). Accordingly, the maximum crop yield advantage (85%) was recorded at treatment 9 where 5t/ha compost applied in combination with 100GR (4t/ha). Similar study also showed that the yield efficiency of rice was increased by 46.6% for plot treated with gypsum and organic matter as compared with the control (Farook and Khan, 2010). Studies also indicated that combined application of gypsum and compost were the most effective combination to increase wheat grain by 208% over control (Zaka et al., 2003). Other similar studies by Joachim *et al.* (2007) and Hanay *et al.*, (2004) also indicated that combined application of gypsum and compost on salt affected soil significantly increased maize yield in Tanzania for two consecutive years as compared with sole application. Gypsum and compost applications to paddy saline soil is effective in improving soil physiochemical, biological properties and enhance the growth and crop yield of rice (Hanay et al., 2004; Tejada et al., 2006; Wong et al., 2009). Other similar study by Kasahun *et al.* (2019) found that combined application of compost and gypsum significantly increased onion yield. Beneficial effect of compost on crop growth and yield has been reported. However, combinations of chemical amendments (gypsum) with compost were more beneficial to cut short the reclamation period and for achieving rapid rehabilitation (Ameen et. al., 2017).

An increased in crop yield is mainly due to application of Gypsum as calcium amendments can prevent the development of sodicity which is directly related to plant growth, crop productivity and crop yields (Wong et al., 2009). Studies showed that soluble Ca^{2+} released by gypsum can be used to reduce the stress effect of Na^{+} on crop yield (Chi et al., 2012). It was known that Ca^{2+} have a stronger charge than Na^{+} , they will replace Na^{+} on exchange sites, causing Na^{+} to be released to the soil solution and be susceptible to removal by leaching. Compost also plays an important role in improving soil quality, structure, basic infiltration rate and nutrient enhancement which resulted in increased crop yield (Saied et al. 2017).

Table 2: Effect of compost integrated with Gypsum on onion yield.

Treatments	Mean Crop yield (Q/ha)	SE Mean	St.Dev	Minimum	Maximum	Relative yield advantage
Main effect for Compost						
0 (control)	237.18 ^f	7.01	21.02	215	275	0.00
2.5t/ha compost	240.03 ^f	7.55	22.65	191.67	260	1.20
5t/ha compost	275.55 ^e	8.20	25.60	216.7	285	16.18
Main effect for Gypsum						
2t/ha Gypsum	284.44 ^e	4.44	13.33	265	300	19.93
4t/ha Gypsum	325.00 ^d	4.82	14.46	310	350	37.03
Interaction effects						
2.5t/ha compost+2t/ha Gypsum	355.77 ^c	6.33	18.99	330	397	50.00
2.5t/ha compost+4t/ha Gypsum	396.40 ^b	2.59	7.77	385	410	67.13
5t/ha compost+2t/ha Gypsum	406.70 ^b	3.05	9.14	395	425	71.47
5t/ha compost+4t/ha Gypsum	430.33 ^a	4.18	12.53	421	458	85.23
LCD (0.05)	25.03					
CV (%)	6.05					
T-test	***					

Main and combined Effect of Gypsum and Compost on EC

The level of Electrical conductivity (EC) of the soil is one of an indicator to describe its salinity status. It was identified that main effects for Gypsum and its interaction with compost significantly ($p < 0.05$) affected EC (mmhoms/cm) of the soil. Low EC (0.36mmhoms/cm) was recorded from treatment nine where 5t/ha compost was applied combined with 100%GR (4t/ha). Maximum EC (3.78mmhoms/cm) was recorded under the control treatment where neither compost nor gypsum was applied (Table 3). EC was not significantly affected by the main effect year indicating that variation in cropping season has no an effect on the level of EC (figure 3). On the other hand, main effect compost was not significantly affected the level of EC but it showed a decreasing trend as the level of compost application was increasing (table3). Other similar studies also revealed that, the application of compost accelerated sodium leaching by increasing CEC of the soil that consequently reduced EC of the soil (Bardhan et al., 2007).

EC showed decreasing by 92% (from 3.78 mmhos/cm to 0.36 mmhos/cm) as the levels of gypsum and compost level of application was increasing (table 4). This was due to reduced concentration of dissolved sodium as a result of gypsum application (Tejada et al., 2006). Similar study also revealed that the integrated application of compost and gypsum reduced EC by 31% as compared with sole application of compost and gypsum (Niazi et al. 2001). It was identified that EC of the soil insignificantly affected ($p < 0.05$) by sole application of compost but highly significantly affected ($p < 0.05$) by sole application of gypsum (table 3). The result was mainly due to the fact that gypsum plays a significant role in the providing a Ca^{2+} cation to replace the exchangeable Na^{+} on the exchange positions and leaching it out from the root zone (Sharma and Minhas, 2005). EC of the soil before treatment application was not significantly ($p < 0.05$) different indicating that the experimental plots have similar EC (table 3).

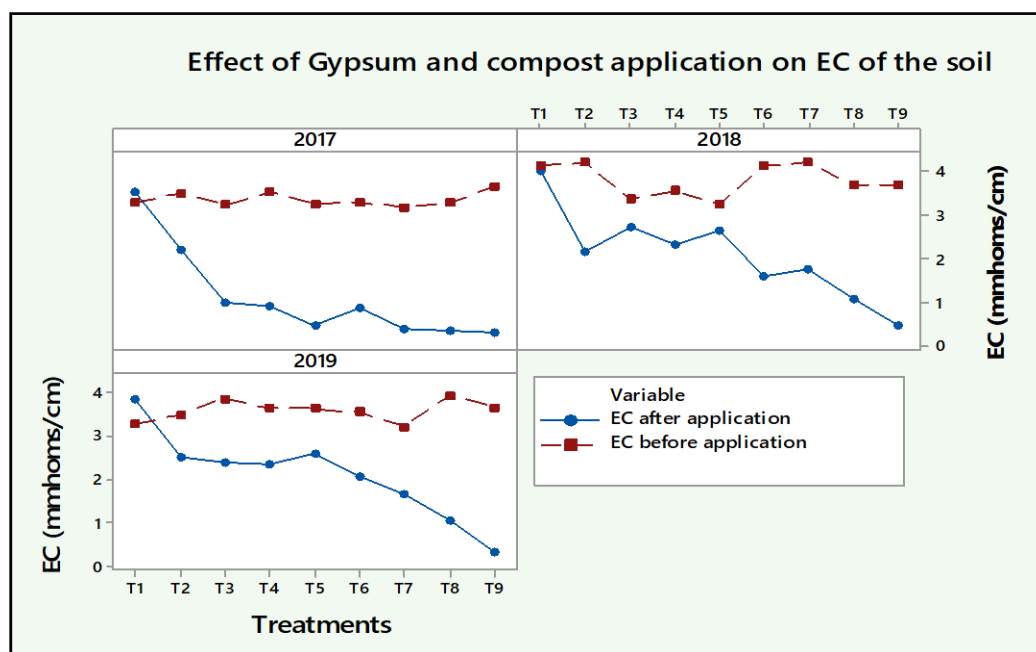


Figure 3: Change in EC after application of the treatments

Treatments:

1. Control
2. 2.5 ton/ha Compost
3. 5t/ha Compost
4. 50% GR (2ton/ha)
5. 100% GR (4ton/ha)
6. 2.5t/ha Compost+50%GR
7. 2.5t/ha Compost +100%GR
8. 5t/ha Compost +50%GR
9. 5t/ha Compost+100%GR

Decreased soil dispersion and lower EC were recorded more in combined application of gypsum and compost than sole application of gypsum and compost (Ghulam et al. 2011).

The study by Muhammad *et al.* (2018) indicated that integrated application of Gypsum and compost reduced EC of the soil from 8.52 dS m^{-1} to 3.0 dS m^{-1} . The reduction of EC might be due to leaching of soluble salts (Na^{+}) into the drainage systems or into the deeper layers of the soil profile (Hanay et al., 2004).

Main and combined Effect of Gypsum and Compost on Exchangeable Sodium (ESP)

Exchangeable sodium percentage (ESP) is the amount of adsorbed sodium on the soil exchange complex expressed in percent of the cation exchange capacity in milli equivalents per 100 g of soil. In other words, it is the percentage of soil exchange sites occupied by Na^{+} , and is calculated by dividing the concentration of Na^{+} cations by the total cation exchange capacity (Qadir et al., 2008).

$$\text{Exchangeable sodium percentage (ESP\%)} = \frac{\text{Exchangeable Na (me/100 g soil)}}{\text{Cation exchange capacity (me/100 g soil)}} \times 100$$

It was identified that the main effect for gypsum significantly ($p < 0.05$) affected ESP. On the other hand, main effect for compost was not significantly affected ESP at similar significance level. The combined effect of Gypsum and compost were highly significantly ($p < 0.05$) affected ESP. Low ESP (1.46%) was recorded from treatment nine where 5t/ha compost applied combined with 100%GR (4t/ha) followed by treatment seven (1.63%) that received 2t/ha compost and 4t/ha gypsum. Maximum ESP (15.97%) was recorded from the control treatment that received neither compost nor gypsum (table4). ESP of the soil before treatment application was not significantly ($p < 0.05$) different indicating that the experimental plots have similar ESP (table 3).

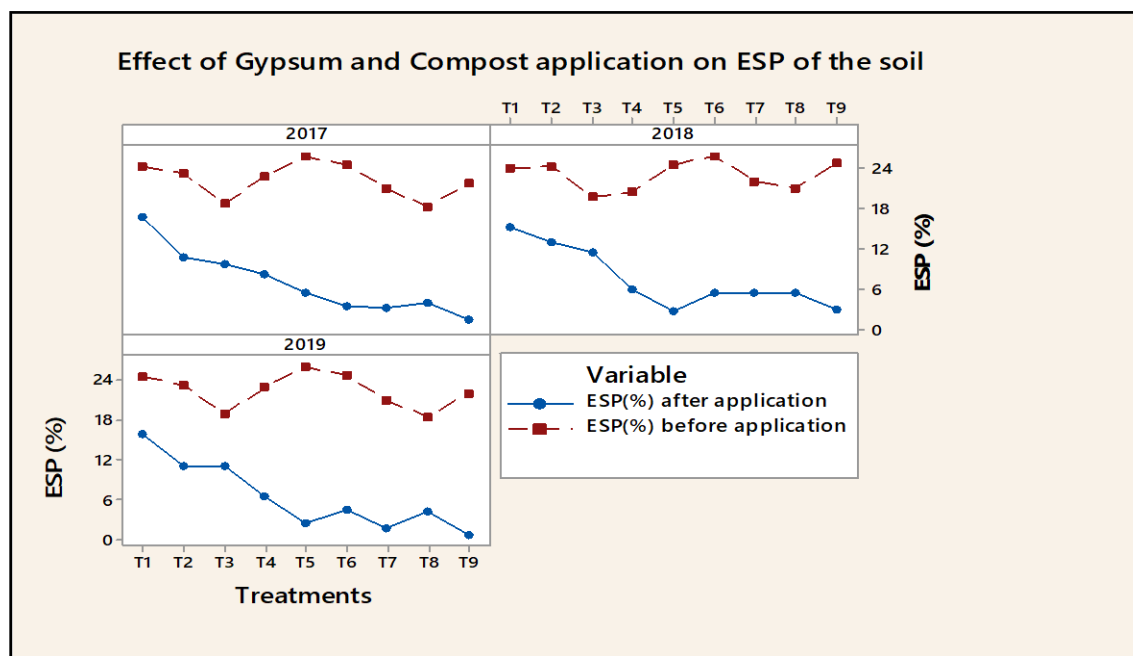


Figure 4: Change in ESP after application of the treatments

Treatments:

1. Control
2. 2.5 ton/ha Compost
3. 5t/ha Compost
4. 50%GR (2ton/ha)
5. 100%GR (4ton/ha)
6. 2.5t/ha Compost+50%GR
7. 2.5t/ha Compost +100%GR
8. 5t/ha Compost +50%GR
9. 5t/ha Compost+100%GR

The levels of ESP showed decreasing trends as the level of compost and gypsum application were increasing (figure 4). However, ESP was not significantly different with the variation in year or cropping seasons. The reduced in ESP was mainly due to adding of Gypsum releases exchangeable Ca^{2+} to replace Na^{+} on exchange sites, causing Na^{+} to be leached to the soil solution (Abbas et al., 2016). Other similar studies also indicated that use of gypsum integrated with organic material like water hyacinth compost and rice straw compost reduced ESP of saline-sodic soils as compared their sole application (Shaaban et al., 2013, Abay and Kasahun, 2019).

Main and combined Effect of Gypsum and Compost on Ex.Calcium (Ca^{2+})

Main effect for gypsum was significantly ($p < 0.05$) affected Ca^{2+} concentration in the soil. On the other hand, Ca^{2+} was not significantly ($p < 0.05$) affected by sole application of compost (table 3). However, Ca^{2+} level increased with the increased level of

compost mainly due to addition of few amount of calcium and improved CEC due to compost application (Clark et al., 2007). The interaction effect of Gypsum and compost on the level Ca^{2+} were highly significant ($p < 0.05$) different indicating that the level of Ca^{2+} level significantly affected by the sole application of gypsum (table 3).

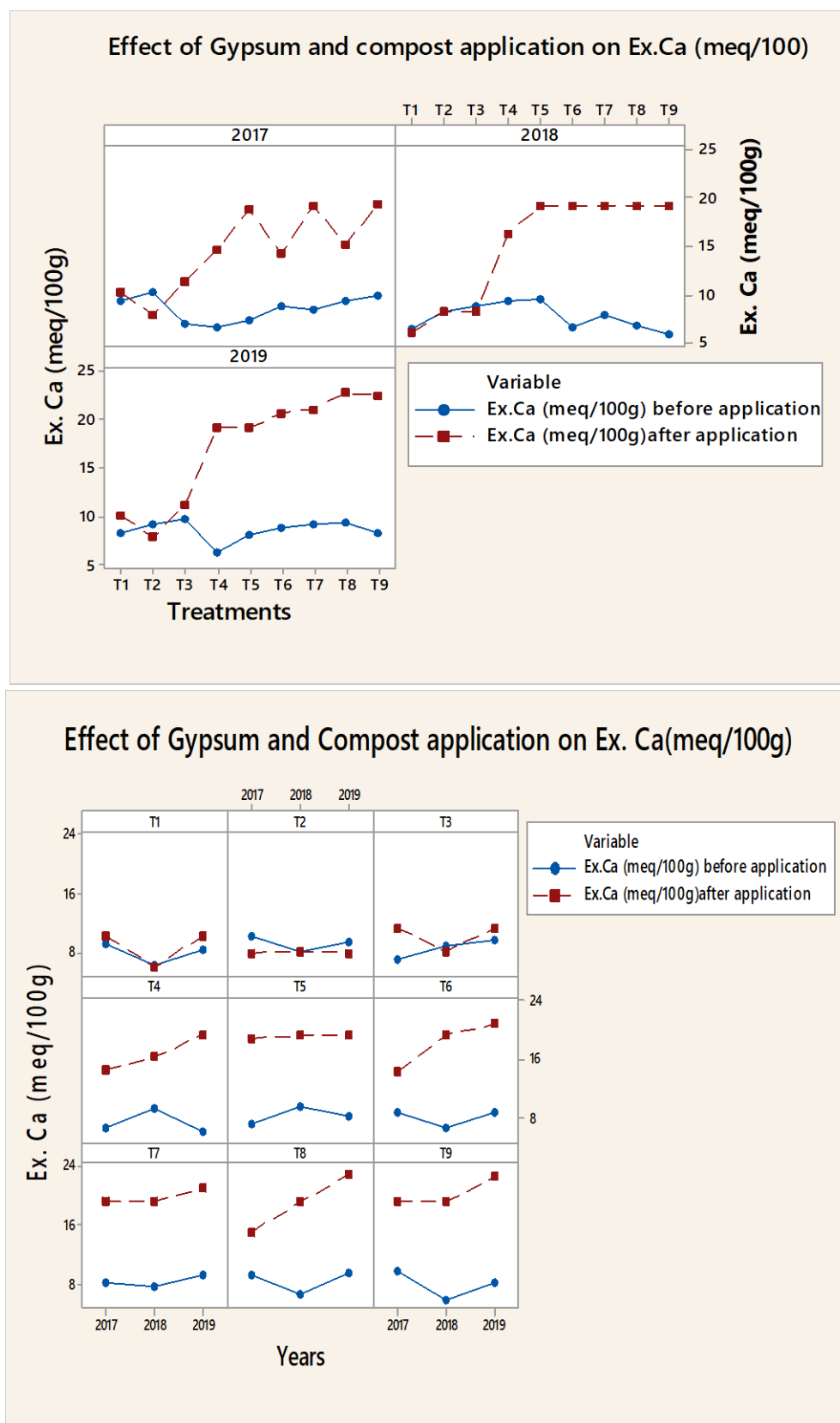


Figure 5: Residual effect of compost and gypsum application on Ex. Ca^{2+} across the years

Treatments:

1. Control
2. 2.5 ton/ha Compost
3. 5t/ha Compost
4. 50%GR (2ton/ha)
5. 100%GR (4ton/ha)
6. 2.5t/ha Compost+50%GR
7. 2.5t/ha Compost +100%GR
8. 5t/ha Compost +50%GR
9. 5t/ha Compost+100%GR

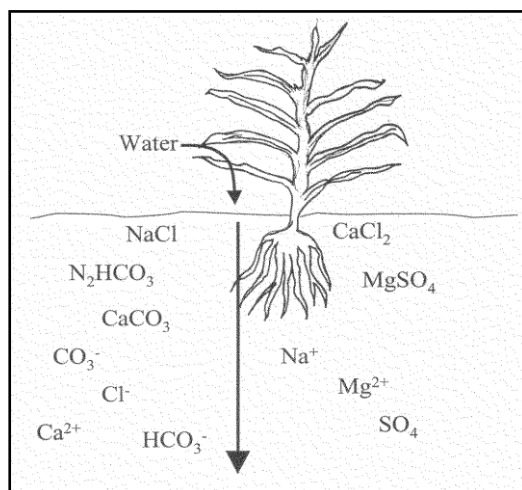
Low Ca²⁺ (7.9meq/100g) was recorded from the control treatment where neither compost nor gypsum was applied. Maximum Ca²⁺ (24.55meq/100g) was recorded from treatment nine where 5t/ha compost applied integrated with 100%GR (4t/ha) followed by treatment seven which was recorded 23.02meq/100g. Ca²⁺ of the soil before treatment application was not significantly ($p < 0.05$) different indicating that the experimental plots have similar Ca²⁺ (table 3). The level Ca²⁺ showed an increasing trend as the level of combined application of compost and gypsum were increased (figure 5). It was increased to 107% where 5t/ha compost was applied in combination with 4t/ha gypsum (table 4). This result seems nearly agreement with (Sharma and Minhas 2005) who found that in addition to removing exchangeable Na⁺, application of gypsum increased the concentration of Ca²⁺ in the soil.

Table 3: Mean separation on effect of Gypsum and Compost application on Soil salinity

Treatments	Dependent variables							
	Initial EC (mmhoms /cm)	Residual EC (mmhoms/ cm)	Initial ESP (%)	Residual ESP (%)	Initial Ex.Ca+2 (meq/100g)	Residual Ex.Ca+2 (meq/100g)	Initial pH	Residual pH
Main effect for compost								
0 (control)	3.80	3.78 ^a	16.01	15.97 ^a	8.02	7.93 ^b	8.43	8.32 ^a
2.5t/ha compost	3.72	3.28 ^a	15.23	13.60 ^a	11.02	8.75 ^b	8.48	7.95 ^a
5t/ha compost	3.92	2.52 ^a	14.95	12.70 ^a	8.43	10.19 ^b	8.35	7.60 ^b
Main effect for Gypsum								
2t/ha Gypsum	4.11	1.90 ^b	20.35	6.87 ^b	10.33	17.62 ^c	8.20	8.41 ^a
4t/ha Gypsum	3.28	0.68 ^c	19.35	3.61 ^{cd}	12.5	21.02 ^a	8.41	8.37 ^a
Interaction effects								
2.5t/ha compost+2t/ha Gypsum	4.3	1.70 ^b	18.35	4.55 ^d	10.2	17.80 ^c	8.13	7.94 ^a
2.5t/ha compost+4t/ha Gypsum	3.35	0.92 ^c	15.68	1.63 ^c	11.58	23.02 ^a	8.33	7.90 ^a
5t/ha compost+2t/ha Gypsum	3.57	1.65 ^b	19.36	4.52 ^d	11.58	17.90 ^c	8.35	7.89 ^a
5t/ha compost+4t/ha Gypsum	4.01	0.36 ^c	20.5	1.46 ^c	11.85	24.55 ^a	8.43	7.87 ^a
LCD (0.05)	0.72	1.12	4.01	2.88	2.32	3.79	0.35	0.50
CV (%)	12.79	18.4	11.43	20.27	18.75	16.21	2.82	4.09
F-test	ns	***	ns	***	ns	***	ns	**

Table 4: Relative change of soil salinity after application of compost and Gypsum

Treatments	Dependent variables								
	Initial EC (mmhos/cm)	Residual EC (mmhos/cm)	Change in EC (%)	Initial ESP (%)	Residual ESP (%)	Change in ESP (%)	Initial Ex.Ca+2 (meq/100g)	Residual Ex.Ca+2 (meq/100g)	Change in Ca2+ (%)
0 (control)	3.80	3.78	0.53	16.01	15.97	0.25	8.02	7.93	1.12
2.5t/ha compost	3.72	3.28	11.83	15.23	13.6	10.70	11.02	8.75	20.60
5t/ha compost	3.92	2.52	35.71	14.95	12.7	15.05	8.43	10.19	20.88
2t/ha Gypsum	4.11	1.90	53.77	20.35	6.87	66.24	10.33	17.62	70.57
4t/ha Gypsum	3.28	0.68	79.27	19.35	3.61	81.34	12.5	21.02	68.16
2.5t/ha compost+2t/ha Gypsum	4.30	1.70	60.47	18.35	4.55	75.20	10.2	17.8	74.51
2.5t/ha compost+4t/ha Gypsum	3.35	0.92	72.54	15.68	1.63	89.60	11.58	23.02	98.79
5t/ha compost+2t/ha Gypsum	3.57	1.65	53.78	19.36	4.52	76.65	11.58	17.9	54.58
5t/ha compost+4t/ha Gypsum	4.01	0.36	91.02	20.5	1.46	92.88	11.85	24.55	107.50

Effect of soil salinity parameters on crop yield**Effect of ESP and Ca²⁺ on crop yield****Figure 6:** Increased salts in root zone can result in decreased water uptake by plant

It was identified that ESP (%) negatively affected crop yield. As the level of sodium (ESP) concentration in the soil increases, the onion yield showed a decreasing trend indicating that high sodium concentration in the soil was a problem to onion production (figure 6). Other similar studies indicated that excess sodium in the root zone reduces the amount of water available to plants and causes the plant to expend more energy to exclude salts and take up pure water. Additionally, if salinity in the soil solution is great

enough, water will be pulled out of the plant cell to the soil solution, causing root cells to shrink and collapse (Brady and Weil, 2002). The effect of these processes is 'osmotic' stress for the plant. Osmotic stress symptoms are very similar to those of drought stress, and include stunted growth, poor germination, leaf burn, wilting and possibly death (figure 7). Thus, any increase in ESP can be at the expense of plant health, and decreases in crop productivity and yield are likely to occur with increasing salinity.

On the other hand, Ca^{2+} has positive relationship with the crop yield. Crop yield showed an increasing trend as the level of Ca^{2+} in the soil was increasing (figure 6). An increased in yield was mainly due to the fact that Ca^{2+} is an important mineral for plant growth and health that consequently improve crop yield (Wright et al., 2008). ESP (%) and Ca^{2+} have a negative relationship. ESP (%) showed a decreasing trend as the level of Ca^{2+} was increasing (Figure 6). Similar studies by different authors also indicated that the increase in Ca^{2+} occurred due to direct application of gypsum (Wright et al., 2018). In this case, Ca^{2+} replaced Na^{+} on exchange sites that was leached down during continuous irrigation so that there was net increase in Ca^{2+} content and very high decrease in the amount of Na^{+} from the soil solution (El-Sanat et al., 2017).

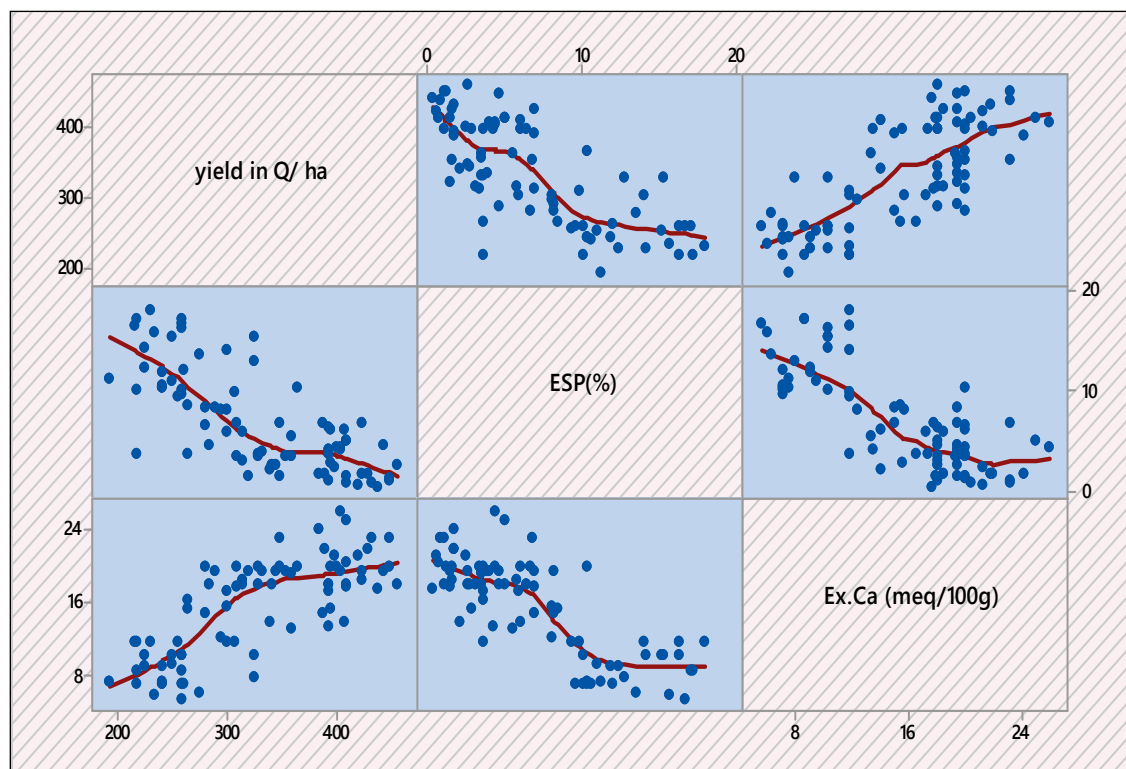


Figure 7: Matrix plot of Onion yield in Q/ha, ESP (%), and Ex. Ca^{2+} (Meq/100g)

Effect of EC and Na^{+} on crop yield

Both EC and Na^{+} have negative relation with crop yield. As the level of Na^{+} increases the EC of the soil increased that consequently reduced crop yield (figure 8). Onion yield showed a reduced trend as the level of Na^{+} and EC of the soil is increased. That is why soil salinity management was required which aimed to reduce the concentration of Na^{+} and EC in the soil. Other similar findings also showed that gypsum and compost applications to saline soil are an effective remediation procedure not only in terms of improving the physical, chemical and biological properties of the soil but also used to enhance the growth and development of crops (Wong et al., 2009). Combined application of compost and gypsum were superior ameliorants to reduce EC and Na^{+} of the soil as compared with their sole application (Hanay et al., 2004).

Effect of Compost and Gypsum application on Soil pH

Soil pH is a characteristic that describes the relative acidity or alkalinity of the soil. Soils are considered acidic if $\text{pH} < 5$, and very acidic if $\text{pH} < 4$. On the other hand, soils are considered alkaline if $\text{pH} > 7.5$, and very alkaline if $\text{pH} > 8$. Soil pH was highly significantly different ($p < 0.05$) among the treatments. pH was very high at the control treatment (8.42), where there was no application of gypsum and compost as compared with other treatments (table). It was identified that the main effect of compost significantly ($p < 0.05$ affect soil pH) different. Soil pH showed a decreasing trend as the level of compost was increased from 2.5 to 5 ton/ha (Table 3). This is mainly due to the fact that application of compost can reduce soil pH as a result of organic acids released

during decomposition of compost (Abbas et al., 2016). On the other hand main and interaction effect gypsum was not significantly ($p < 0.05$) affect soil pH. This is mainly due to an increased in concentration of calcium from gypsum application has little influence in reducing soil pH (Brady and Weil, 2002). Studies also indicated that compost decreased soil pH by 9.5%, gypsum by 3.9%. Other similar studies also showed that pH was lowered by 5.7% when compost and gypsum were applied in combined form as compared with the control treatments (Niazi et al. 2001).

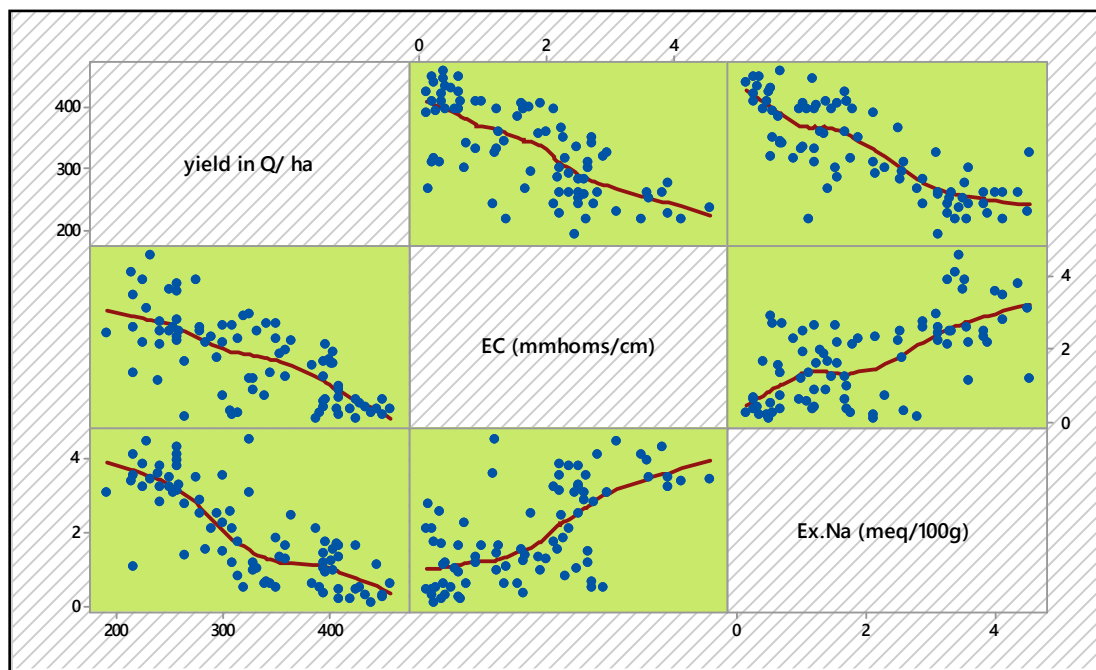


Figure 8: Matrix plot of Onion yield in Q/ha, EC (mmhoms/cm), and Ex. Na+ (Meq/100g)

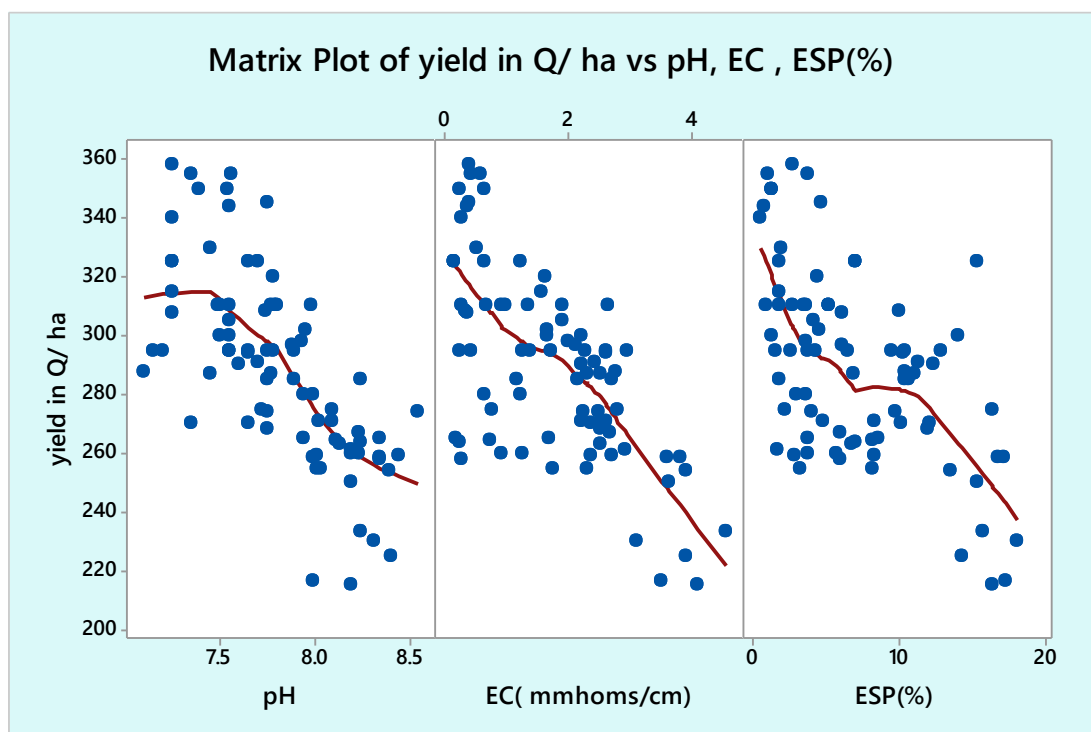


Figure 9: Matrix plot of crop yield vs soil pH, EC and ESP

Crop yield showed a negative relationship with the level of soil pH (figure 9). Onion yield showed a decreasing trend as the level of pH increased to the alkaline. This was mainly due to the fact that the availability of some plant nutrients is greatly affected by soil pH (Halvin et al. 2002). It has been determined that most plant nutrients are optimally available to plants within 6.5 to 7.5 pH range, plus this range of pH is generally very compatible to plant root growth (Anwar et al.,2004). At alkaline pH values, greater than pH 7.5 for example, phosphate ions tend to react quickly with calcium (Ca) and magnesium (Mg) to form less soluble compounds. At acidic pH values, phosphate ions react with aluminum (Al) and iron (Fe) to again form less soluble compounds (Zia et al. (2006).

Economic Analysis

The partial budget analysis was done following the standard methodology designed by (CIMMYT, 1988) to select the most economically important soil salinity amendments. Accordingly, the maximum net benefit (780240.00Birr) was obtained by treatment 9 where 5t/ha Compost + 100%GR (4t/ha) was applied. However, the MRR was high (34.48birr) for treatment seven where 2.5t/ha compost was applied in combination with 4t/ha gypsum. In this case, even though net benefit for the treatment 9 is higher as compared with the rest of the treatments, its MRR is lower than other treatments of combined application. The Marginal rate of return (MRR) measures the amount of benefit gained for additional unit of cost or investment. The net benefit showed an increasing trend as the level of compost and gypsum application was increasing. However, final recommendation will be based on the MRR that determine the profitability of an investment. Similar studies by Wienhold and Trooien (2005) and Abdel-Fattah (2012) reported that gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$) amendment is the most economical amendment used on sodic soil management.

Table 4: Partial Economic analysis for onion yield

Treatments	Mean yield in Q/ha	Input cost /ha (ETB)	Labor costs /ha (ETB)	Total variable cost/ha (ETB)	Market price of Onion/Q (ETB)	Gross income /ha	Net income/ ha in (ETB)	MRR (ETB)
0 (control)	237.18	36500	28020	64520	2000	474360.00	409840.00	0
2.5t/ha compost	250.55	36350	30520	66870	2000	501100.00	434230.00	10.38
5t/ha compost	275.55	36200	33020	69220	2000	551100.00	481880.00	15.33
2t/ha Gypsum	284.44	42100	28020	70120	2000	568880.00	498760.00	15.88
4t/ha Gypsum	325.00	47700	28020	75720	2000	650000.00	574280.00	14.68
2.5t/ha compost+2t/ha Gypsum	355.77	41950	30520	72470	2000	711540.00	639070.00	28.83
2.5t/ha compost+4t/ha Gypsum	375.55	41800	30520	72320	2000	751100.00	678780.00	34.48
5t/ha compost+2t/ha Gypsum	406.70	41800	33020	74820	2000	813400.00	738580.00	31.92
5t/ha compost+4t/ha Gypsum	430.33	47400	33020	80420	2000	860660.00	780240.00	23.30

5. CONCLUSIONS AND RECOMMENDATIONS

Soil and plant health can be adversely affected by the presence of excessive salts in soils. Understanding how salt-affected soils develop and identifying their characteristics is crucial to managing salt affected areas. Choosing which management techniques to employ to salt-affected soils will depend on the nature and extent of the problem, cost and available resources.

This project was conducted with the aim to reduce the effect of soil sodicity problem on onion yield through the application of compost and gypsum. An effective reclamation procedure for sodic soils is removal of undesirable Na^+ concentration in the soil by application of some Ca^{2+} source like gypsum. Accordingly, the combination of compost and gypsum proved to be the best soil amendment for reducing soil pH, ESP and EC of the soil. In addition, with increasing rate of the application of gypsum and compost used in reclamation process, the more decrease in soil salinity problem and increased in crop yield. Application of compost also played an important role in improving soil pH that directly affects the availability of major plant nutrients.

Therefore, based on the above findings, it was highly recommended to apply the combination of compost and gypsum for reclamation of salt affected soil. Accordingly, based on the marginal rate of return calculated for the treatments, farmers and other beneficiaries were recommended to effectively reclaim their salt affected soils by applying gypsum at the full rate (100% GR) integrating it with compost (2.5t/ha) where 34.48birr was gained higher than the remaining treatments.

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Conflicts of Interest

The authors declare no conflicts of interest.

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